

UPPER ATMOSPHERIC DENSITIES BETWEEN 155 and 165 km BY OBSERVATION OF A10 CLOUDS

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In a recent article, von Zahn (1970) has compared mass densities derived from satellite drag data for an altitude of 150 km with densities determined by mass spectrometers, EUV extinction measurements and observation of luminescent clouds. Results from this last method are summarized in Table 3 of his article and an average density value is deduced. The two values given by Rees *et al.* (1969) which are quoted have now to be replaced in that table by the revised ones (Rees *et al.*, 1970) which are 34 per cent lower. The fact that such a correction reduces, by 10 per cent, the average of all the data obtained from luminescent clouds indicates that new measurements are still needed to make a statistical analysis worthwhile. In addition, the scatter of the various values has been up to 50 per cent of the mean value and the probable error is of the order of 20 per cent. As specified by von Zahn (1970), part of the scatter of the data is due to the various choices made by the different authors for the physical parameters required for the interpretation of the measurements. These parameters are the mean collisional diameter of the interdiffusing molecules and the mean atmospheric molecular weight; even if there is no great uncertainty about the latter, values of the collisional diameter have still to be assumed.

Another source of error which has apparently not received much attention up to now is the influence of the vertical motion of luminescent clouds. Evidence for this will be given in the present note which is primarily intended to report new results obtained in the frame-work of the sounding rocket programme of the European Space Research Organisation (ESRO). The experiments were performed by means of the payloads S 64-1 and S 64-2 launched from Sardinia on July 6 and 13, 1969 respectively. The launch times were 2030 and 2021 LMT. Releases took place at low (158 and 155 km) and high (275 and 278 km) altitudes. For both flights the A10 clouds formed at low altitudes were observed during sufficiently long periods to allow good diffusion measurements to be made. Cameras equipped with lenses having apertures of $f/2.8$ and $f/0.87$ were used to photograph the clouds at a zenith distance of the order of 15° . In particular on July 13, the half gaussian diameter of the low altitude cloud was measured over a period of 660 sec and a significant increase with time of the diffusion rate was observed. This phenomenon was correlated with the upward motion of the cloud deduced from triangulation data (Ackerman and Van Hemelrijck, 1971). The photographic observation of the high-altitude clouds was of too short duration to allow worthwhile diffusion measurements to be made.

Atmospheric densities, ρ were computed by means of the relation

$$\rho = \frac{3 M_1}{8\sigma^2 D_{12} N} \left(\frac{RT}{2M^*\pi} \right)^{1/2} \text{ g cm}^{-3} \quad (1)$$

where R and π have their usual meaning and N is the Avogadro's number. The temperature T , was deduced from the analysis of the A10 spectra. The diffusion coefficient D_{12} of A10 into the atmosphere was obtained by plotting the square of the gaussian half width of the clouds versus time. A mean atmospheric molecular weight M_1 , of 23.5 g mole^{-1} was chosen (Nicolet, 1964) leading to a value of the reduced mass M^* , equal to 15.2 g mole^{-1} .

The results are summarized in Table 1 where the temperatures are also listed for the two experiments. The value of the collisional diameter σ used in Equation (1) has been taken equal to $3.32 \times 10^{-8} \text{ cm}$ after comparison (Simon, 1971) of the data available for various molecules including oxygen compounds. The density value marked with an asterisk has been deduced from photographs taken through an interference filter centered at 4670 \AA in the $\Delta v = +1$ sequence of the A10 spectrum.

TABLE 1. ATMOSPHERIC TEMPERATURES (T) AND DENSITIES (ρ) DEDUCED FROM THE OBSERVED A10 CLOUDS

Payload (N)	Altitude (km)	T (°K)	ρ (gcm ⁻³)
S 64-1	160	645	1.40×10^{-12}
S 64-2	156	660	1.55×10^{-12}
	156*	660	1.76×10^{-12}
	165	660	1.12×10^{-12}

* Measurement at 4670 \AA .

The first conclusion to be drawn from Table 1 relates to the vertical motion of the clouds observed in these experiments and described in more detail by Ackerman and Van Hemelrijck (1971). Particularly in the case of the S 64-2 experiment, the same cloud allows density determinations to be made over an altitude range of 10 km. If only the release altitude (155 km) had been considered, the assigned density of 1.12×10^{-12} g cm⁻³ would have been in error by 60 per cent. As shown in Fig. 1, the results reported here agree within 10 per cent or better with the values of the CIRA (1965) mean atmospheric model, which are lower.

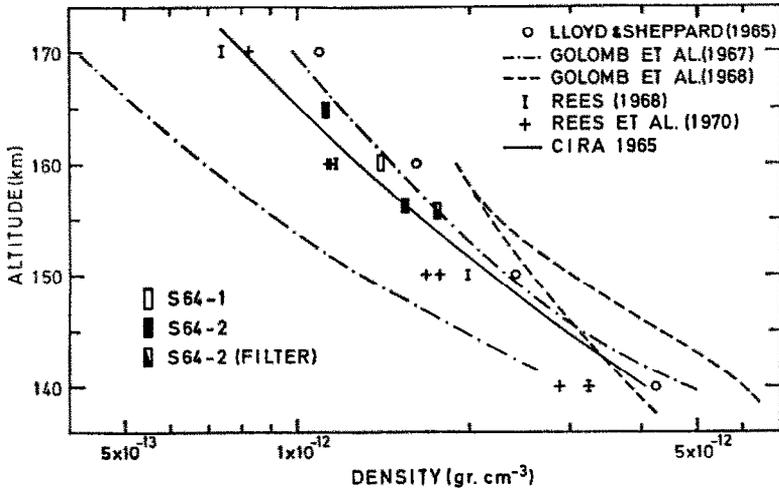


FIG. 1. OBSERVED AND MODEL ATMOSPHERIC DENSITIES VS. ALTITUDE BETWEEN 140 AND 170 km.

The results of other authors are also shown. The comparison is, however, not straightforward. All experimenters seem to have used a mean atmospheric molecular weight of 28, Lloyd and Sheppard (1965) excepted, since they used a value taken from a model. Unfortunately, they did not have a temperature measurement. Golomb *et al.* (1967, 1968) have deduced the densities from the self diffusion coefficient of air D_{11} taken equal to $1.25 \times D_{12}$. On the other hand our choice of the mean collisional diameter and atmospheric molecular weight corresponds to a ratio $D_{11}/D_{12} = 1.4$. This difference could account for our results being 12 per cent lower than those reported by Golomb *et al.* (1967, 1968). The use by Rees *et al.* (1970) of a mean atmospheric molecular weight equal to 28, and of a mean collisional diameter 3.6 per cent higher than used in this work, would tend to yield values 5 per cent higher than those reported here by us while these are already higher by approximately 20 per cent.

As already pointed out by von Zahn (1970) the scatter of density values at about 150 km should not be as great as the observations of luminescent clouds seem to indicate. This discrepancy would not be much reduced if, in the reduction of the measurements, the same values of molecular parameters had been used. The results obtained with the ESRO payloads S 64-1 and S 64-2 show that vertical motions of artificial clouds could possibly explain some of the scatter observed in the results.

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